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Chapter 18
Ecosystem services and ecological role of birds in insect and pest control

Abstract: Agricultural ornithology is an emerging science that renders great ecosystem services. Most of the bird species play a vital role in agriculture by managing pest and rodent populations. In agricultural countries like India, this field has a special importance in protecting agricultural crops from invading insect pests and, thereby, preventing economic losses to farmers in an ecofriendly manner. In addition, birds aid farmers by reducing invertebrate crop pests, yet they are seldom used in Integrated Pest Management (IPM) practices. Nonetheless, several bird species have a substantial influence on agricultural productivity. To develop practical IPM approaches, it is necessary to understand bird flocking and their behavior at different stages of crops, so that the agricultural yield will be enhanced. Developing strategies on overall aspects help complete essential knowledge gaps around the complex roles of birds in agricultural systems. Although many better works have been started, a lot is yet to be done in order to stabilize the ecological approaches. This book chapter describes the ecosystem services provided by birds and agricultural ornithology advancements, highlights difficulties and information shortages, and suggests future research possibilities.

18.1 Introduction

Agricultural ornithology deals with the role of birds in pollination, seed dispersal, crop pest control, crop grain management, and associated ecosystem services. Birds play a significant part in crop insect management in all agricultural ecosystems, whether dry or irrigated; it primarily focuses on bird ecology and management in agroecosystems. It also collects scientific data on birds and controls insects [1]. Agriculture crops offer birds a concentrated and reliable food supply such as insects, other arthropods, rodents, grains, etc. Birds are the most effective insect predators among vertebrates, because they can swiftly gather

Acknowledgment: The authors would like to acknowledge their affiliated institutes. They would like to acknowledge Dr. R. Venkitachalam, C. Vijaya Kumar, R. Suryaprahasan, V. Ilaiya Bharathi, and G. K. Dinesh for bird photo plates.

https://doi.org/10.1515/9783110771558-018

in great numbers upon a pest outbreak and protect various agriculture crops, and hence, they serve as excellent natural insect pest managers [2]. In agroecosystems, most bird species are insectivorous and play an important role in maintaining a population of insect pests, and thereby, they are beneficial to farmers [3]. Another study estimated that the prey biomass consumed by insectivorous birds ranges from 400–500 million metric tons per year [4] Birds are one of the key pollinator groups in the animal kingdom, rendering service to about 80% of plants that depend on other animals for pollination. Seed dispersal is another important ecosystem service carried out by birds that helps sustain green plants and trees. However, granivorous bird species cause severe damage to crops, leading to crop loss. Thus, crops, birds, and insects have mutualistic and antagonistic relationships and a significant ecological connection that supports biological cycles and food chains. Few studies have examined this complex and delicate relationship, and more thorough studies should be done. This book chapter deals with the role of birds in the biological control of insects and pests in various agroecosystems.

18.2 Ecosystem services of birds in the agroecosystem

Nature delivers both massive ecosystem services (ES) and ecosystem disservices (EDS). However, the affinity between the two is less well-recognized [5]. As in the case of birds, they are flying vertebrates and recognized as sources of various ES [6] and function as an effective alternative to chemical pesticides [7]. Based on the Millennium Ecosystem Assessment, ecosystem services have been categorized into four categories as provisioning services, regulating services, supporting services, and cultural services [8]. Birds provide multifaceted environmental services, including nutrition cycling through droppings (supportive services), pest and bug management (regulatory services), scavenging, and seed dispersion (cultural services), besides their behavior-driven services [9] (Figure 18.1). The potential ecosystem services and disservices by birds and their ecological relationship between various organisms are complex (Figure 18.2).

18.2.1 Regulating services of birds

Birds are important biocontrol agents in regulating pests and insects in agricultural landscapes. Insectivorous birds such as Black-backed Puffback (*Dryoscopus cubla)*, the Cape White-eye (*Zosterops virens*), the Tawny-flanked Prinia (*Prinia subflava*), the Gorgeous Bush-shrike (*Telophrous viridis*), and the Brown-hooded Kingfisher (*Halcyon*

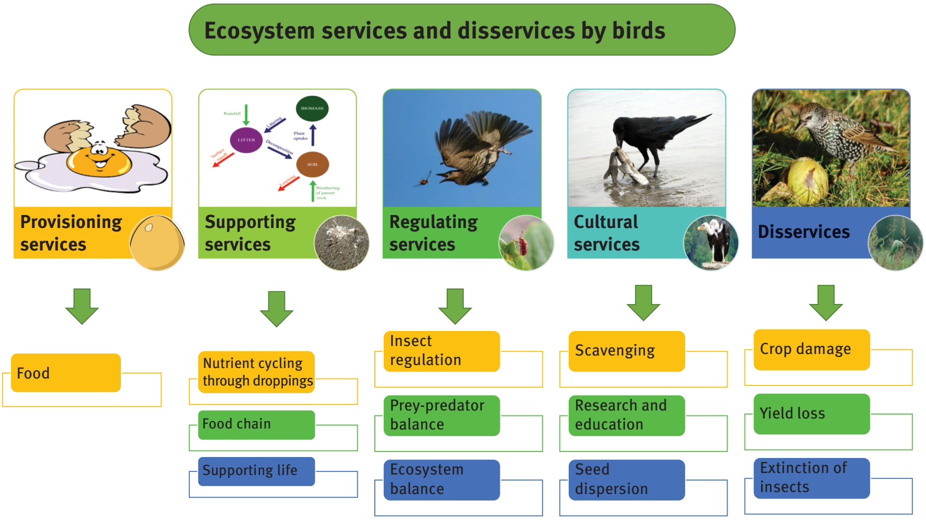


Figure 18.1: Ecosystem services and disservices provided by the bird.

albiventris), Cattle egret (*Bubulcus Ibis)*, Common wood shrike (*Tephrodornis pondicerianus)*, Hoopoe (*Upupa epops*), Black drongo (*Dicrurus macrocercus)*, Indian roller (*Coracias benghalensis*), and Asian green bee-eater (*Merops orientalis*) are well-known insectivorous bird species across agroecosystems [10–12]. Some of the birds are shown in Figure 18.3. These well-identified insect predators have not been documented well on their economic benefits in different agroecosystems. Only a few scientific reports are available on the economic effects of birds on biological pest management. Both ES and EDS are subject to change in response as the landscape structure changes [5, 13], and farmers often see surviving natural areas as lost land and the locations where pests thrive [14]. Loss of natural habitat for birds affects these ecosystem service providers, resulting in the increase of the pest population. Thus, a trade-off between ES and EDS may exist, mediated by landscape composition. Other agricultural systems have benefited significantly from closeness to the forest areas in bird variety and predator hunting success [15]. Crop raiding by birds occurred exclusively in near-natural vegetation and caused a yield loss of around 26% [5]. However, bird biocontrol was more effective in the natural vegetation habitat. According to the research done in Macadamia farms of South Africa, biological management by birds and bats had an economic effect of about USD 5,000 ha/year. Another study points out that the revenue losses were reduced by bird pest management to the value of USD 1,595/ha as income gain. Bats and birds enhance the ecosystem services when released near artificial roosts and nest sites, but species-specific preference studies of birds are yet to take off well. It is critical to educate farmers since many are unaware of the advantages of birds [5]. To boost the bird populations as biological control, artificial nesting and roosting places may be built to attract birds to agricultural regions with little

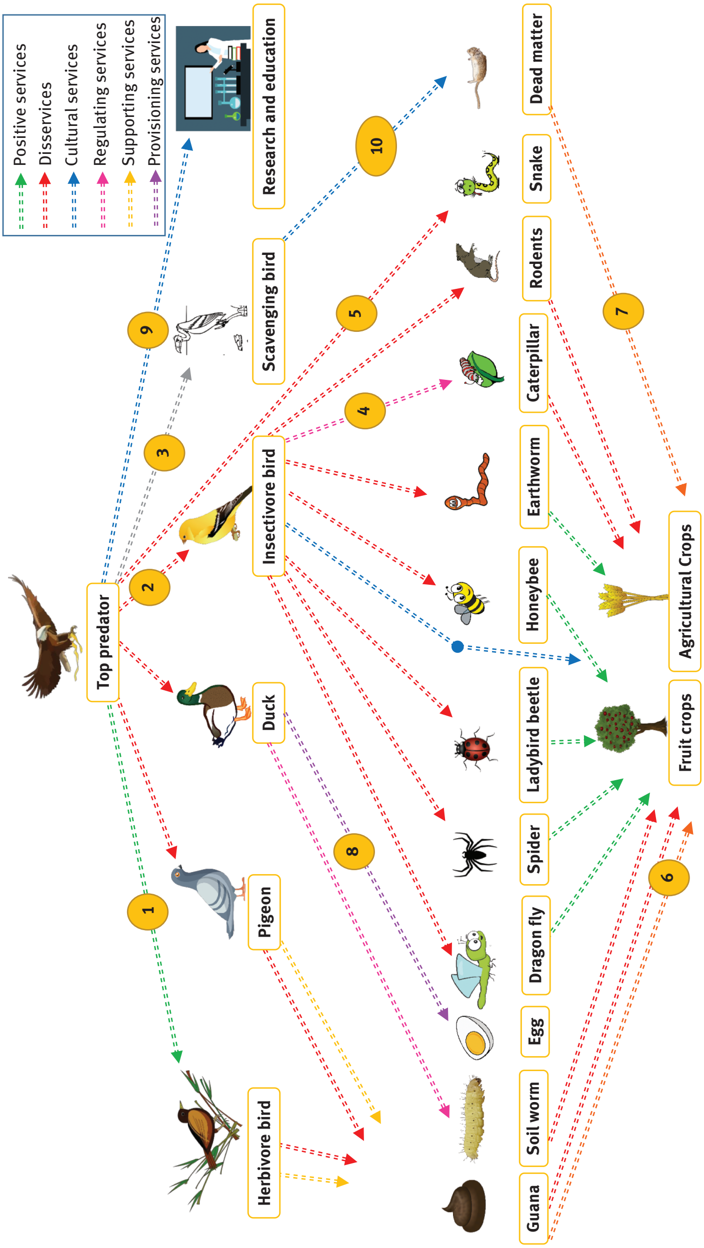


Figure 18.2: The potential services and disservices by birds in an agroecosystem.
Notes: 1. Top predator predating herbivore birds that are harmful for crops; 2. Top predator predating insectivore birds that are beneficial for crops; 3. Top predators not having any guild on scavenging birds, hence they are neutral; 4. Insectivore bird eating caterpillar, by which it is reducing the population and they are classified as regulating services; 5. Top predators predating snakes, which it is indirectly leading to yield losses by rodents; 6. Guana or faecal

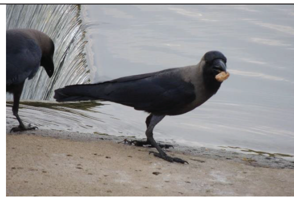
		
Red-naped Ibis (*Pseudibis papillosa*) feeding on soil dwelling worms and insects (regulating services)	Indian Peafowl (*Pavo cristatus*) feeding on soil dwelling worms and insects (regulating services)	Yellow-billed Babbler (*Turdoides affinis*) eating some insect (regulating services)
		
Wholly-necked Stork (*Ciconia episcopus*) feeding on soil dwelling worms and insects (regulating services)	Common Myna (*Acridotheres tristis*) searching food on waste litters (cultural services)	House Crow (*Corvus splendens*) scavenging on waste litter nearby agricultural irrigation structures (cultural services)
		
Rose-ringed Parakeet (*Psittacula krameri*) feeding on fruits (disservices)	Asian Paradise -Flycatcher (*Terpsiphone paradisi*) feeding on dragonfly - beneficial insect (disservices)	Indian Grey-hornbill (*Ocyceros birostris*) using tree to watch the insect nearby fields
		
House Sparrow (*Passer domesticus*) storing grains in tree cravices (cultural services)	Indian roller (*Coracias benghalensis*) utilizes trees nearby in fields as a perch	Black kite (*Milvus migrans*) flying near agricultural field to feed rodents

Figure 18.3: Various Ecosystem services and disservices provided by the common agricultural field birds.

Figure 18.2 (continued)
matter by birds are both harmful and beneficial, the faecal matter on economic parts may be considered as poor quality, and if the faecal matter added to the soil it is beneficial to soil for nutrient cycling and they are classified as supporting services; 8. some farm birds such as duck may eat the harmful soil worms and larvae, also it provides nutritious meat and egg, they are classified as provisioning services; 9. Birds are useful for research and education, it also have aesthetic value, hence it is classified as cultural services; 10. Some scavenging birds may clean up the ecosystem by eating dead matter, it is classified into cultural services.

natural habitat nearby [7]. This would be more cost-efficient than using chemical pesticides to control pest species below an economic threshold level [16]. Biodiversity research in specific agricultural regions is incumbent to developing suitable designs for birds as biological pest control.

18.3 Birds' niche in paddy ecosystem

Wetlands play a vital role in our natural environment. Wetlands are described as the "kidney of the landscape" because they function as the downstream receivers of water and waste from both natural and human resources [17]. Wetlands provide shelter for roosting, nesting, and foraging environments to waterfowl, fish, amphibians, reptiles, and many plant species at critical life phases and as protection from harsh weather [10]. They also serve as stepping stones or corridor habitats for migratory bird species such as waterfowl and waders. Wetlands offer habitat and shelter for many species and aid resilience of species as a means to overcome population decline [9]. Studies on birds in rice fields and the number of reported species are listed in Table 18.1.

Table 18.1: Studies on birds in rice fields and the number of reported bird species [9, 10, 21].

Location	Cultivation system	No. of species	Source
Indian subcontinent			
Ahmedabad, Gujarat, India	Seasonal	28	[21]
Bangalore district, Karnataka, India	All-year	131	[21]
Etawah and Manipuri districts, Uttar Pradesh, India	Seasonal	114	[21]
Kerala, India	All-year	133	[21]
Kheda district, Gujarat, India	Seasonal	65	[37]
Ludhiana, Punjab, India	All-year	68	[26]
Ludhiana, Punjab, India	All-year	23	[27]
Mysore and Coorg districts, Karnataka, India	All-year	68	[21]
Nellore district, Andhra Pradesh, India	All-year	62	[21]
Pondicherry, India	All-year	34	[31]
Ranga Reddy district, Andhra Pradesh, India	All-year	56	[35]
Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India (Conventional rice fields)	All-year	26	[9]

Table 18.1 (continued)

Location	Cultivation system	No. of species	Source
Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India (Organic rice fields)	All-year	25	[9]
The Indian subcontinent	All-year	89	[32]
The Indian subcontinent	All-year	59	[39]
Uttaranchal, India	Seasonal	58	[21]
West Bengal, India	Seasonal	67	[21]
Other countries			
Bangladesh	Flooded	88	[21]
Kurunegala district, Sri Lanka	All-year	61	[38]
Nepal	Seasonal	175	[21]
Pakistan	Seasonal	60	[33, 34]
Southwestern Louisiana, USA	All-year	37	[25]
Sri Lanka	All-year	73	[36]

The Indian subcontinent is home to approximately 1300 bird species. Rice fields serve as artificial wetlands and are home to various bird species. Rice is an important food crop in India, with 81 lakh hectares planted nationwide [18]. The Indian subcontinent has the highest farmland cover per unit area globally, with rice (*Oryza sativa*) as the second most significant crop; Irrigated paddy fields in tropical Asia are the source of one-third of the world's rice [19]. Paddy fields in south India may have three rice seasons (e.g., in Tamil Nadu, India); other locations may have one (e.g., Uttar Pradesh (India), Pakistan, and Bangladesh) or two harvests in a year (e.g., parts of Karnataka in India). At least close to 351 species utilize rice fields in the subcontinent, even though just 2.7% of the subcontinent's birds nest in these fields [21]. Diverse aquatic creatures inhabit the paddy field environment, and they are considered as ecosystem engineers, since they play an essential part in the food web's dynamics [20, 22]. Algae, macroinvertebrates, vertebrates, microorganisms, and mosquito vector species thrive in this environment [23].

Birds have an ecological and functional value in the rice wetlands that act as a habitat to live and survive. Paddy fields are occupied mainly by waterfowls and ducks throughout the season, with certain species from nearby habitats only visiting the fields on rare occasions. For example, Lapwings, Baya weaver, Munia, and Larks require nesting season in moist habitats of rice-growing areas. Farmers' intervention will be less in the fields during the initial rice-growing season after transplanting,

since it will be maintained in a submerged condition for two to three months. At this time, is the fields are best suited as bird nesting grounds. According to a study in Louisiana (USA), 37% of the birds recorded (37 species) inbreed in paddy fields. In contrast, just 2.7% of birds have been observed to breed in paddy fields [24, 25].

Paddy fields are being used by wintering birds in the northern subcontinent, although migratory birds use paddy fields throughout their stay. The rice is harvested after the fields have been drained. Many bird species exploit the dried fields, ripened grains, and grain leftovers left after harvesting. After the dry summer season, fields are flooded and plowed, attracting diverse bird species in large numbers. The observations made from the studies [9] show that the plowing followed by irrigation exposes many grubs, cocoons, and pests from the topsoil layer in rice fields; hence, the birds are attracted more during tillage practices when they effectively forage on the soil insects [21]. The utilization of fields by the birds appears to be less in machine-tilled fields, but this difference has not been documented scientifically.

18.3.1 Relationship between birds and insects in rice wetlands

A comparative study on the role of birds in organic and inorganic paddy ecosystems by Tamil Nadu Agricultural University, India, revealed that 26 species of birds were found in the inorganic rice ecosystem, compared to 25 species in the organic rice fields. However, the bird population in the organic environment was 29.69% greater than in the inorganic environment [9, 10]. Granivorous birds were seen during harvesting stages in both organic and inorganic rice. The common birds seen in the organic rice fields include Indian Pond Heron, Egret, Common Sandpiper, Red Wattled Lapwing, and White-browed Wagtail, whereas, in inorganic rice fields, the Indian Pond Heron, Red-wattled Lapwing, Egret, Common myna, and Black drongo were the most common birds [9, 10]. A similar study in 1990 studied the bird population of an intensively maintained area in Ludhiana and found 68 species [26]. Among them, 10 were grain eaters, 12 were omnivores, 38 were insectivores, and 8 had mixed foraging habits. The top four species (two omnivores and two grain eaters) accounted for 47% of the occurrence of 68 bird species. Also, 38 insectivorous species accounted for barely 30% of the birds. Another study was carried out to find agricultural bird diversity in the Ludhiana district's rice fields [27]. Nearly 23, with 12 non-passerine and 11 passerine species, belonging to 6 orders, 17 families, and 21 genera were found. Another study in the United States compared the count and diversity of bird species on organic and conventional farms in Florida [28]. They discovered that mixed field plantings, margins, adjacent matrix of woodland, and hedgerow had the highest bird abundances. This is because the insectivorous birds rely on the insect food available in fields [29, 30]. Major studies on birds in rice fields are enlisted in Table 18.1.

The feeding pattern of birds in the diversified agroecosystems varies according to the habitats [40]. Weaverbirds and Munia choose rice fields with more vegetation

complexity than resource availability. The findings imply that predator avoidance rather than resources influence the reported foraging pattern by avians found in the agroecosystems. Some scientists reported that a few common species dominate disturbed habitats, and agricultural areas are considered highly disturbed habitats [41]. Hence, diversity is less in artificial wetlands than natural wetlands. The overall abundance of birds and richness in agroecosystems does not differ between open and partially wooded regions [42]. However, trees in the surrounding landscape altered the abundance of several common species. Studies by Indian scientists summarized the data of birds in paddy fields found in the Indian subcontinent [21]. The rice ecosystem birds and their target insect species are enlisted in Table 18.2.

Table 18.2: Rice ecosystem birds and their target insect species [9, 10].

Common name	Scientific name	Family	Order	Target insect species
Asian Open Bill Stork	*Anastomus oscitans* (Boddaert) 1783	Ciconiidae	Ciconiiformes	Wide range of insects
Black Drongo	*Dicrurus macrocercus* (Vieillot) 1817	Dicruridae	Passeriformes	Grasshopper *Atractomorphalata* (Mochulsky, 1866), Green leafhopper *Nephotetixvirescens* (Distant, 1908)
Black Kite	*Milvus migrans* (Boddaert) 1783	Accipitridae	Accipitriformes	Grasshopper *Atracto morphalata* (Mochulsky, 1866) Green leafhopper *Nephotetix virescens* (Distant, 1908)
Blue Rock Pigeon	*Columba livia* (Gmelin) 1789	Columbidae	Columbiformes	Ant *Solenopsis geminate* (Fabricius, 1804)
Blue-tailed Bee-eater	*Merops philippinus* (Linnaeus) 1766	Meropidae	Coraciiformes	Grasshopper *Atractomorphalata* (Mochulsky, 1866)
Brahminy Kite	*Haliaster Indus* (Boddaert) 1783	Accipitridae	Accipitriformes	Rice bugs *Leptocorisaoratoria* (Fabricius, 1764)
Bronze-winged Jacana	*Metopidius indicus* (Latham) 1790	Jacanidae	Charadriiformes	Larva, worms, and ants
Cattle Egret	*Bubulcus ibis* (Linnaeus) 1758	Ardeidae	Pelecaniformes	Rice leaf folder *Cnaphalocrocismedinalis* (Guenee, 1859)

Table 18.2 (continued)

Common name	Scientific name	Family	Order	Target insect species
Common Myna	*Acridotheres tristis* (Linnaeus) 1758	Sturnidae	Passeriformes	Swarming caterpillar *Spodoptera mauritia* (Boisduval) 1833
Common Sandpiper	*Acititishy poleucos* (Linnaeus) 1758	Scolopacidae	Charadriiformes	Worms, larvae
Darter	*Plotus anhinga* (Linnaeus) 1766	Anhingidae	Suliformes	Larvae
House Crow	*Corvus splendens* (Vieillot) 1817	Corvidae	Passeriformes	Ant *Solenopsis geminate* (Fabricius, 1804), Brown planthopper *Nilaparvatalugens* (Stal, 1854), Stink bugs *Nezaraviridula* (Linnaeus, 1758)
Eurasian Collared-Dove	*Streptopelia decaocto* (Frivaldszky) 1838	Columbidae	Columbiformes	Ant *Solenopsis geminate* (Fabricius, 1804)
Common Greenshank	*Tringa nebularia* (Gunnerus) 1767	Scolopacidae	Charadriiformes	Larvae
Grey Wagtail	*Motacilla cinerea* (Tunstall) 1771	Motacillidae	Passeriformes	Ant *Solenopsis geminate* (Fabricius, 1804), larvae, worms
Indian Pond Heron	*Ardeola grayii* (Sykes) 1832	Ardeidae	Pelecaniformes	Damselfly *Agriocnemispygmaea* (Rambur, 1842), Dragonfly *Sympetrum flaveolum* (Selys, 1854)
Indian Roller	*Coracias benghalensis* (Linnaeus) 1758	Coraciidae	Coraciiformes	Grasshopper *Atractomorphalata* (Mochulsky, 1866) Green leafhopper *Nephotetixvirescens* (Distant, 1908)
Little Egret	*Egretta garzetta* (Linnaeus) 1766	Ardeidae	Pelecaniformes	Damselfly *Agriocnemispygmaea* (Rambur, 1842), Dragonfly *Sympetrum flaveolum* (Selys, 1854)
Indian Peafowl	*Pavo cristatus* (Linnaeus) 1758	Phasianidae	Galliformes	Cutworm *Spodoptera litura* (Fabricius, 1775), Rice caseworm *Nymphuladepunctalis* (Guenee) 1854, Rice hispa *Dicladispaarmigera* (Oliver) 1808

Table 18.2 (continued)

Common name	Scientific name	Family	Order	Target insect species
Grey-headed Swamphen Moorhen	*Porphyrio poliocephalus* (Latham) 1801	Rallidae	Gruiformes	Worms, larvae
Red-wattled Lapwing	*Vanellus indicus* (Boddaert) 1783	Charadriidae	Charadriiformes	Cutworm *Spodoptera litura* (Fabricius, 1775), Rice caseworm *Nymphuladepunctalis* (Guenee) 1854, Rice hispa*Dicladispaarmigera* (Oliver) 1808
Spotted Munia	*Lonchura punctulata* (Linnaeus) 1758	Estrildidae	Passeriformes	Ants and small insects
Spotted Owlet	*Athene brama* (Temminck) 1821	Strigidae	Strigiformes	Cutworm *Spodoptera litura* (Fabricius, 1775), Grasshopper *Atracto morphalata* (Mochulsky, 1866)
Tricolored Munia	*Lonchura malacca* (Linnaeus) 1766	Estrildidae	Passeriformes	Ants and small insects
Eurasian Whimbrel	*Numenius phaeopus* (Linnaeus) 1758	Scolopacidae	Charadriiformes	Larvae
White-breasted Waterhen	*Amaurornis phoenicurus* (Pennant) 1769	Rallidae	Gruiformes	Larvae
White-browed Wagtail	*Motacilla maderaspatensis* (Gmelin) 1789	Motacillidae	Passeriformes	orthopterans, caterpillars, and spiders
White-throated Kingfisher	*Halcyon smyrnensis* (Linnaeus) 1758	Alcedinidae	Coraciiformes	Ants, larvae, and small insects

18.3.2 Birds–insects relationship in other crop fields

Insectivorous birds have a broad range of eating preferences, from chasing insects to digging in the dirt and woodlands. Approximately 60% of known species are insectivorous [43]. About 545 species of birds use agricultural areas for food and other activities, and 25 species have been observed to harm crops and fruits. The majority of the identified species are insectivorous [44]. Sturnidae and Turdidae starlings and thrushes eat a lot of insects and other arthropods [4]. These insects provide vital protein and other nutrients to newborn birds. The bird population in the Ludhiana district was studied while sowing maize, in which the results showed that species diversity (H'), species richness, and uniformity (E) were 2.53, 17, and 0.89, respectively [45]. Similar research was done in the boll formation stages of the cotton field, in which 26 bird species were documented [27]. Fourteen insectivorous/omnivorous species used T-perches to forage insect pests in the adjacent cotton plants. In the wheat fields of Ludhiana, Punjab, 19 different species of birds from five orders, 11 families, and 13 genera were identified. Bird species recorded in various states of India through agroecosystem studies were elucidated as a map (Figure 18.4).

During wheat harvest, the bird population showed successive patterns that connected to plant types [46]. In 1762, the Common Myna *Acridotheres tristis* was imported in Mauritius to control the red locust, *Nomadacris septemtasciata*. Several investigations on red locust gut content analyses have demonstrated that many birds rely on insect pests for food, which includes Brahminy Starling Rosy Starling, Gray-headed Starling, Yellow Wagtail, Spotted Owlet, etc. Some omnivores, including the Black-throated weaver bird, Baya Weaver, Large Grey Babbler, House sparrow, and Babbler species, eat insects and perform a dual function. For example, the barn owl eats only rodents, but the Spotted Owlet mostly feeds on Coleopteran and Lepidopteran adults. Several studies have attempted to measure the function of birds in pest management [47].

There are 14 bird species that were identified as *Helicoverpa armigera* predators in chickpea cropping systems, reducing the larval population by 73% and increasing crop output. Aside from direct predation, these birds cause natural epizootics by spreading germs and viruses in the host insect habitat. *Bacillus popillae* var. *Holotrichiea* causes milky sickness in *Holotrichia consanguinea*. It was also found that Myna and house sparrow feed on both healthy and infected H. armigera larvae, aiding the spread of NPV [48]. Drongo feces contain high amounts of NPV poly occlusion bodies (POBs) @ 7×10^8 POBs per gram of feces. Raptors eat 60–70% orthopterans. Adults with young ones may hunt on 20 mice per day; hence, raptors are the best rodent pest-controlling bird. The Spotted Owlet eats insects (54%), followed by rodents (36%), micro mammals (10%), and unidentified vertebrates (10%). The relative number of insects was greatest, with Orthoptera (24%) followed by Coleoptera (19%) and Dermaptera (11%) [49].

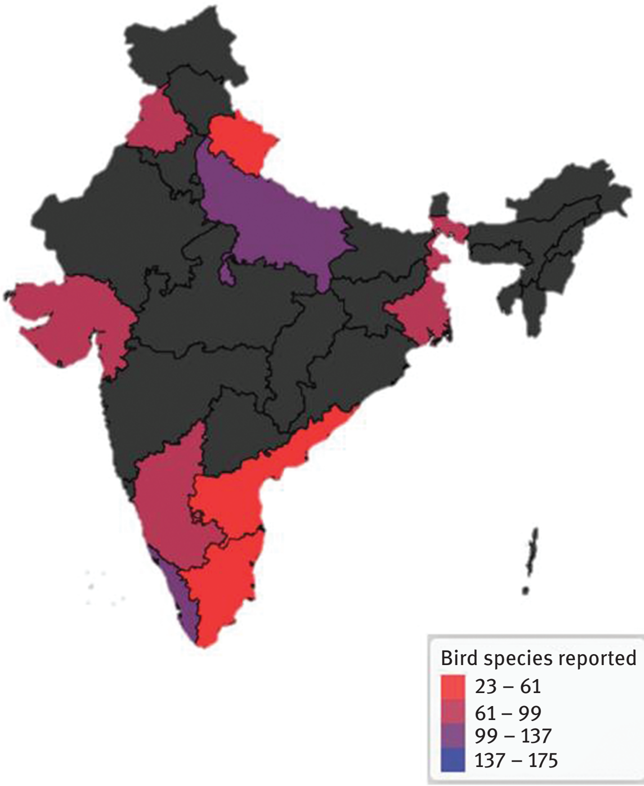


Figure 18.4: Bird species recorded in various states of India by agroecosystem studies.

An exclusive study on strawberries found that 3.8% of insect damage was reduced by an insectivorous bird [50]. In a comparative study of food preference among plowed and unplowed crop fields of pigeon pea, sorghum, maize, and cow pea, the maximum number of birds was recorded in unplowed fields and the least insectivorous birds were recorded in sorghum. In sorghum, H. armigera was the most preferred species [51]. Jungle babbler (*Turdoides striatus*), a widely spread subtropical insectivorous passerine, is considered beneficial to an agroecosystem, as they devour voraciously on insect matter, especially *Helicoverpa armigera*. The Manila tamarind, Tamarind *Pithecolobium dulce* attracts significant numbers of Rosy Starling, which suppressed *H. armigera* and *Spodoptera litura* in summer groundnut, but the adjacent region without manila trees showed an increased prevalence of such pests, requiring pesticide treatment. Mulberry fruits also have an ecological role in keeping insectivorous (beneficial) birds in the neighboring agricultural system. The *Salvadora persica* fruit attracts 18 bird species and aids in the natural management of *H. armigera* [52]. The Cattle egret is an essential bird predator in agricultural cropping systems, capturing insect pests, forming an integral part of IPM. In wheat

crop, the role of birds in the natural regulation of a polyphagous lepidopteran pest, *H. armigera*, was studied in Gujarat, which concluded that the birds preferred insects over maturing wheat grains [53]. The potential of insectivorous birds to regulate the pests in woody and fruit crops has been evaluated in Spain by exclusion study and artificial nesting. The result shows that Great tit (*Parus major*) and sparrows (*Passer domesticus and P. montanus*) increased over time and controlled the Greater wax moth and sentinel caterpillars. It was found that Great tits (*Parus major*) reduced the insect damage by 19% and increased fruit yield by 66% in commercial apple orchards [53]. By providing nest boxes to insectivorous birds in Californian vineyards, the population of Beet armyworms (*Spodoptera exigua*) was reduced by 3.5 times [54]. In Costa Rica, birds reduced half an infestation of coffee berry borer beetles (*Hypothenemus hampei*) [55]. In Indonesia's bird and bat exclusion study, 31% increased pest abundance, decreasing final crop yield [56]. Several workers have also reported that natural enemies like predatory birds and insectivorous birds help in control of fruit pests such as aphids, mites, psyllids, and leaf miners by natural enemies [57].

Insectivorous birds, which decrease the number of leaf-eating insects, can enhance forest tree growth by reducing leaf damage [58]. Insectivorous birds and bats are considered effective arthropod predators in the tropical agricultural ecosystem [59]. Insect pests from the order Coleoptera and Lepidoptera (especially immature form) are effectively reduced by the bird population buildup across different habitat types [60]. Thirty-eight species of insectivorous birds belonging to 17 families under 26 genera were recorded at the maize agroecosystem in the Bengaluru region [61]. Insectivorous bird activity was also recorded in Bt and Non-Bt maize crops, and it was observed that higher insectivorous birds are under organic systems, large woodlots, dense trees, and thick hedgerows. The well-known insect pests of cacao, the cacao pod borer, and *Helopeltis bugs* were not affected by bat and bird exposure. The main reason appeared to be that the pod borer spends most of its immature stages hidden inside the pod and, therefore, is not a visible prey [62]. Nocturnal arthropods strongly declined in abundance due to exposure to nocturnal predators, including birds [63]. Likewise, organic farming is associated with increased insectivorous bird numbers, largely due to high spatial and habitat heterogeneity in the cultivated units benefiting insectivorous over granivorous birds [64]. Generalist species are favored because conventional farming reduces habitat quality by homogenizing landscapes [65]. Insectivorous bird species and their target insects in other crops are listed in Table 18.3.

18.4 Economic worthiness of insectivorous birds

Alternative use of synthetic chemicals and insectivorous birds may provide an environmentally sound and economically viable alternative in many agroecological cropping systems [70]. Birds can economically benefit crop plants across the tropical and

Table 18.3: Insectivorous bird species and their target insects in other crops [9, 10, 61, 66–69].

Common insectivorous birds	Scientific name	Target insects	Crops
Ashy Prinia	*Prinia socialis*	*Aphis gossypii*; Hymenoptera and Hemiptera insects	Guava; Cotton
Asian Brown Flycatcher	*Muscica padauurica*	Different species of insects	Different species of crops
Asian Palm-Swift	*Cypsiurus balasiensis*	Aerial insectivore; Preys insects on flight	Different species of crops
Asian Paradise (Flycatcher)	*Terpsiphone paradisi*	Different species of insects	Different species of crops
Barn Swallow	*Hirundo rustica*	Different species of flies, including horn flies, face flies, horse flies; leafhoppers, grasshoppers, wasps, crickets, moths, and beetles	Horn flies, face flies, and horse flies are domestic animals' pests, whereas crickets are household pests. Moths, beetle, leafhoppers, and polyphagous are pests of different crops.
Black-Backed Kingfisher or the oriental dwarf kingfisher	*Ceyx erithaca*	katydid	Household pest
Black-Billed Cuckoo	*Coccyzus erythropthalmus*	Tent caterpillar nest, Malacosoma	Pest of an urban and foreign tree.
Blackbirds	*Turdus merula*	Diamond-Back Moth	Cruciferous vegetable
Black-Cheeked Woodpecker	*Melanerpes pucherani*	Wasp	Generalized predator
Black Drongo	*Dicrurus macrocercus*	Pod borer larvae – *Helicoverpa armigera*	Pigeon pea, chickpea, maize, and sorghum
Black-Rumped Flameback	*Dinopium benghalense*	Stem borers (moths and beetles)	Cardamom, coffee, and cocoa
Blue-Cheeked Bee-Eater	*Merops superciliosus*	*Vanessa* adult	Generalized predator

Table 18.3 (continued)

Common insectivorous birds	Scientific name	Target insects	Crops
Blue-Throated Flycatcher	*Cyornisru beculoides*	Wide range of insect species	Different species of crops
Boat-Tailed Blackbird (Green-Tailed Grackle)	*Quiscalus major*	Cabbage Looper	Cabbage
Botteri's Sparrow	*Peucaea botterii*	*Helicoverpa Spp*,	Polyphagous pest
Brain fever bird or Indian Hawk Cuckoo	*Hierococcyx varius*	Cricket – *Gryllodes melanocephalus*, Weaver ant – *Oecophylla smaragdina*, Cotton stainer – *Dysdergus superstitious*, Sand burrowing insect – *Schyzodactylus monstruosu*, Adult and larva of *Agrotis ipsilon*, Cotton stainer nymphs beetle – *Anomala*, Mole cricket – *Gryllotalpa*, Tobacco grasshopper – *Attractographa*	Guava, jackfruit, sapota (chiku), paddy, ragi, sorghum, tobacco, and cotton
Brewer's Blackbird, Baltimore Oriole, English Sparrow (house sparrow), Warbling Vireo	*Euphagus cyanocephalus, Icterus galbula, Passer domesticus, Vireo gilvus*	Rose Weevil, Canker Worm	Rose, Deciduous forest, shade forest, and ornamental trees
Bronze Grackle (Common Grackle), Yellow-Headed Blackbird, English Sparrow (house sparrow), Vesper Sparrow, Migrant Shrike (Loggerhead Shrike)	*Quiscalus quiscula*, *Xanthocephalus xanthocephalus*, *Passer domesticus*, *Pooecetes gramineus*, *Lanius ludovicianus*	Armyworm	Polyphagous
Cattle Egret	*Bubulcus ibis*	Spodoptera, Helicoverpa	Sunflower, groundnut, and potato
California Gull	*Larus californicus*	Mormon Cricket	Household pest

Table 18.3 (continued)

Common insectivorous birds	Scientific name	Target insects	Crops
Cedar Bird (Cedar Waxwing)	*Bombycilla cedrorum*	Elm Leaf Beetle	Leaf-chewing insect of an elm tree
Chin-Spot Puffback	*Batis molitor*	Tree looper	Pest of forest tree and fruit crop
Chippy (Chipping Sparrow)	*Spizella passerina*	Cabbage Worm, Pea Louse	Cabbage, pea
Common Hoopoe/ Eurasian Hoopoe	*Upupa epops*	Mole cricket – *Gryllotalp*, Sand burrowing insect – *Schyzodactylus monstruosu*, Adult and larva of *Agrotis ipsilon* and *spilosoma obliqua*	Pulse crops like chickpea, pigeon pea; oilseed crops like castor, sunflower, and groundnut
Common Iora	*Aegithina tiphia*	Variety of insect species and spiders	Different species of crops
Common tailorbird	*Orthotomus sutorius*	Aphids	Mustard, guava, cotton, cowpea, and beans
Crow (Am. Crow), Robin (American Robin)	*Turdus migratorius*	White Grub (June beetle)	Sugarcane, groundnut, and many other crops
Crow Blackbird (Common Grackle)	*Quiscalus mexicanus*	Periodical Cicada	Loudest insect
Eurasian Blackbird	*Turdus merula*	Wide species range	Different species of crops
Forest Wagtail	*Dendronanthus indicus*	Wide insect species range	Different species of crops
Grasshopper Sparrow, Greater Roadrunner, American Kestrel, Common Black Hawk, Corn Bunting, Lesser Kestrel, Lilac Breasted Roller	*Ammodramus savannarum, Geococcyx californianus, Falco sparverius, Buteogallus anthracinus, Emberiza calandra, Falco naumanni, Coracias caudatus*	Grasshopper	Pest of many crops

Table 18.3 (continued)

Common insectivorous birds	Scientific name	Target insects	Crops
Great Grey Shrike	*Lanius excubitor*	Insect species belongs to Orthoptera, Hymenoptera, Lepidoptera, Coleoptera, and Heteroptera	Different species of crops
Great Tit	*Parus major*	*Helicoverpa armigera* and other Lepidoptera insects; Also insects belonging to Orthoptera, Neuroptera, Coleoptera, Heteroptera, Myriapoda, Formicidae, Gasteropoda; larvae belonging to Symphita	Cotton, sorghum, pulses, groundnut, tomato
Greenish Warbler	*Phylloscopus trochiloides*	Diverse insect targets	Different species of crops
Grey Wagtail	*Motacilla cinerea*	*Plutellama culipennis*, *Brevicoryne brassicae* and *Aphis craccivora*,	Cotton, Cabbage, peas, field bean, and guava
Hairy Woodpecker	*Leuconotopicus villosus*	Cecropia Moth, Tussock Moth	Polyphagous, Blueberry
Indian Crow	*Corvus plendens*	Borer – *Adisuraatkinsoni*, sand borrowing insect – *Schyzodactylusmonstruosu, Cricket – Brachytripsachattinu, Darkling beetle – Opatrum sp., Mole cricket – Gryllotalpa*	Tomato, field beans, groundnut, sorghum, millets, cotton, pulses
Indian roller	*Coracias benghalensis*	Rhinoceros beetle – Oryctus rhinoceros, Mole cricket – Gryllotalpa	Groundnut, ragi, pigeon pea, cotton, cucurbits, Guava
Indian wren warbler, fledglings	*Prinia inornata*	Hairy caterpillars, aphids, defoliators	Ragi, millets, groundnut, pulses

Table 18.3 (continued)

Common insectivorous birds	Scientific name	Target insects	Crops
Jack snipe (Wilson's Snipe)*, Curlews, Upland plover (Upland Sandpiper), Plovers, Quail (No. Bobwhite), Prai-Rie Chicken, Blackbirds, Yellow-Headed Blackbird, Bobolink, Western meadow lark, Orioles, Sparrows, Robin (American Robin)	*Lymnocryptes minimus, Numenius spp, Bartramia longicauda, Colinus virginianus, Tympanuchus cupid, Turdus merula, Xanthocephalus xanthocephalus, Dolichonyx oryzivorus, Sturnella neglecta, Icterus, Turdus migratorius*	Rocky Mountain Locust	Polyphagous
Large-Billed Leaf Warbler	*Phylloscopus magnirostris*	Many species of insects	
Little Green Bee-Eater	*Merops orientalis*	*Aphis craccivora, Pieris brassicaae; Apis florea, A. mellifera, A. dorsata and A. cerana*.	Pea, cabbage, cauliflower
Little Swift	*Apus affinis*	Aerial insectivore; Insects belong to Diptera, Hymenoptera, Hemiptera, and Homoptera	Different species of crops
Magnolia Warbler	*Setophaga magnolia*	Spruce budworm,	Pest of Spruce
Myna adults	*Acridotheres tristis*	Ash weevil–*Myllocerous discolor,* Weaver ant – *Oecophylla smaragdina,* Driver ant – *Dorylu,* Rice grasshopper, beetle – *Anomola,* Darkling beetle	Pigeon pea, paddy, jackfruit, guava, sapota (chiku), custard apple
Myna Fledglings	*Acridotheres tristis*	Insect species of Orthoptera, Lepidoptera, Coleoptera, Hymenoptera, *Trichoplusia,* and other defoliators	Sunflower, cotton, pigeon pea, maize, sorghum

Table 18.3 (continued)

Common insectivorous birds	**Scientific name**	**Target insects**	**Crops**
Myrtle Warbler, Blackpoll Warbler, Oregon Chickadee (Black-Capped Chickadee)	*Setophaga coronata, Setophaga striata, Poecile atricapilla*	Plant lice (Aphids)	Polyphagous
Oriental Honey Buzzard	*Pernis ptilorhyncus*	Larvae of Paper wasps – *Polistes* spp.	Generalized predator
Paddy Field Pipit	*Anthus rufulus*	Diverse insect species	Different species of crops
Paddy field Warbler	*Acrocephalusa gricola*	Diverse insect species	Different species of crops
Pied Bushchat	*Saxicola caprata*	*Helicoverpa armigera* and other insects	Sorghum, Pulses, cotton, groundnut, and tomato
Red-Rumped Swallow	*Hirundo daurica*	Various insect species belong to Hymenoptera, Homoptera, Coleoptera, and Diptera	Different species of crops
Red-Shafted Flicker (N. Flicker)	*Colaptes auratus cafer*	Codling Moth	Different species of crops
Red-Throated Pipit	*Anthus cervinus*	Different insects	Different species of crops
Road Runner	*Geococcyx californianus* (the greater roadrunner) *Geococcyx velox* (The lesser roadrunner)	Passion-Vine Caterpillar	Passion flower
Rose-Breasted Grosbeak Cliff Swallow	*Pheucticus ludovicianus*	Potato Beetle	Potato and sweet potato
Rufous Woodpecker	*Celeus brachyurus*	Diversified target species	Different species of crops
Oriental Magpie Robin	*Copsychus saularis*	*Helicoverpa armigera* and other insects	Sorghum, pulses, cotton, groundnut, and tomato

Table 18.3 (continued)

Common insectivorous birds	Scientific name	Target insects	Crops
Starling, Western Meadowlark	*Sturnus vulgaris, Sturnella neglecta*	Cutworms	Cereals and vegetables
Tawny Flanked Prinia	*Prinia subflava*	Aerial insectivore; Insects belonging to Hemiptera and Hymenoptera	Different species of crops
Thick-Billed Warbler	*Acrocephalus aedon*	Diversified insect species	Different species of crops
Tickell's Blue Flycatcher	*Cyornis tickelliae*	Diverse insect species	Different species of crops
Valley Quail (CA Quail)	*Callipepla californica*	Black Olive Scale	Olive
Verditer Flycatcher	*Eumyias thalassinus*	Wide range of insects	Different species of crops
Western Crow (Am. Crow)	*Corvus brachyrhynchos*	Climbing Cutworm	Maize
Western Meadowlark	Sturnella neglecta	Coulee Cricket	Household pest
White-Bellied Fantail	*Rhipidura euryura*	Wide range of insects	
White-Breasted Nuthatch	*Sitta carolinensis*	Pear Psylla	Pear
White-Browed Fantail	*Rhipidura aureola*	Wide range of insects	
White-Crowned Sparrow	*Zonotrichia leucophrys*	Aphis (Rose Aphid)	Rose
Wire-Tailed Swallow	*Hirundo smithii*	Flies including horn flies, face flies, horse flies, leafhoppers, grasshoppers, crickets, moths, beetles, wasps.	Different species of crops
Wood shrike	*Tephrodornis pondicerianus*	Diverse insect targets	Different species of crops
Yellow-Billed Cuckoo	*Coccycus americanus*		

Table 18.3 (continued)

Common insectivorous birds	**Scientific name**	**Target insects**	**Crops**
Yellow-Billed CuckooBaltimore Oriole, English Sparrow (House Sparrow), Cedar Bird (Cedar Waxwing), Yellow Warbler, Robin (American Robin), Blue Jay, Orchard Oriole	*Coccyzus americanus, Icterus galbula, Passer domesticus, Bombycilla cedrorum, Setophaga petechial, Turdus migratorius*	Walnut Caterpillar, Forest Tent Caterpillar, Catalpa Sphinx, Orchard Tent Caterpillar	Walnut, forest tree, Catalpa, trees
Yellow-Billed Cuckoo, Kingbird (E. Kingbird), Great-Crested Flycatcher, Phoebe (E. Phoebe), Wood-Pewee (E. Wood-Pewee), Orchard Oriole, Baltimore Oriole, English Sparrow (House Sparrow), Chippy (Chipping Sparrow), Field Sparrow, Song Sparrow, Chewink (E. Towhee), Cardinal, Scarlet Tanager, Cedar Bird (Cedar Waxwing), Red-Eyed Vireo, Warbling Vireo, Yellow Warbler, Catbird (Grey Catbird), Carolina Wren	*Colaptes auratus cafer, Tyrannus tyrannus, Myiarchus crinitus, Sayornis phoebe, Contopus sordidulus, Icterus spurius, Passer domesticus, Spizella passerine, Spizella pusilla, Melospiza melodia, Pipilo erythrophthalmus, Cardinalis cardinalis, Piranga olivacea, Bombycilla cedrorum, Vireo olivaceus, Vireo gilvus, Setophaga petechial, Dumetella carolinensis, Thryothorus ludovicianus*	Leaf-miner	Polyphagous
White-Browed Wagtail	*Motacilla madaraspatensis*	*Aphis craccivora*, *Plutellama culipennis* and *Brevicoryne brassicae*	Peas, field beans, cabbage, guava, and cotton
White-Naped Tit	*Machlolophus nuchalis*	Pod Borer/American Bollworm – *Helicoverpa armigera*	Sorghum, cotton, groundnut, and pulses
White Wagtail	*Motacilla alba*	*Plutellama culipennis*, *Aphis craccivora* and *Brevicoryne brassicae*,	Peas, field beans, cabbage, guava, and cotton

temperate zones [71]. It has also been estimated that the expenditure on bird ranges adds between 100–400 billion USD per annum to the world's economy and showed birds were responsible for increased production of coffee worth US$310/ ha by controlling coffee berry borer, *Hypothenemus hampei* through bird predating [55]. In addition, birds saved farmers from post-harvest costs of removing mummified almonds and gave a positive net return of AUD 25–275/ ha averaged across almond orchards [72]. Based on gut contents analysis, it was observed that each bird consumes around 2,100 Casebearer larvae, estimated to add the worth of US$2900 to the pecan industry [73].

Tropical studies revealed that the success of birds as predators of insect pests in agricultural landscapes is correlated with native forest proximity. Lemon-bellied white-eye (*Zosterops chloris*) occurs in both forest habitats and coffee plantations, and it plays an important role in suppressing insect pests population in a coffee plantation, and the pest control is enhanced when it is planted at forest proximity [15]. The cabbage looper population has been reduced by 21%, and in broccoli too, insectivorous birds have reduced the two-caterpillar species [74]. Birds killed an average of 41% of overwintering codling moths, *Cydia pomenella,* in walnut orchards [75]. Various studies reported that between 13–99% of the overwintering stage of Codling Moth were consumed by birds, especially near the habitat. The setting of nest boxes increases the density of Great Tits (a relative of chickadees), thereby increasing apple yields by 66% [7, 76]. Birds help reduce olive fruitflies in pupae stages. They consume 65–71% of the pupae in the soil. Dark-Eyed Juncos in large flocks of 50 to 150 birds consume large numbers of insects, as it was found that 23,000 to 70,000 Pear Psylla females, with a potential to produce around 7 to 23 million eggs, were preyed on by the birds. Another study of gut contents analysis of Black-Capped Chickadees, Red-Breasted, and Golden-Crowned Kinglets Nuthatches contained large numbers of winter psyllas [77]. Installation of bird nest boxes has greatly increased the abundance of Western Bluebirds and their ability to insects predation in the vineyards. The highest removal of insects, i.e., 59%, was seen closest to the bird boxes. DNA analysis of fecal matter showed that birds were not consuming natural enemy insects as only 3% of the natural enemies were reported in their diet [54]. Songbirds reduced the population of alfalfa weevils by over 33% [78]. Birds reduced corn insect pests by 34–98% in different studies. Birds were estimated to reduce 20–26% of leaf damaging grasshoppers in millet [79]. Examination of fecal matter collected from the active mud cavity previously nested by birds reported 18–84% of pest insects and around 34–70% of cutworms in the fecal analysis [80]. In feeding trials using nonparasitized and parasitized Armyworms, preference of birds was tested, and it was seen that birds strongly preferred the larger nonparasitized insects than the parasitized ones [28]. Birds reduced grasshoppers selectively in different sites by 25–55% [81, 82]. When pest abundance ranged from medium to high, European Starlings ate 40–60% of pasture grubs [83]. Releasing wild falcons in New Zealand vineyards reduces pests by 78–83% and grape damage by 55–95% [84]. Pest reduction by various birds and crops is listed in Table 18.4.

Table 18.4: Pest insects and other invertebrates managed with beneficial birds.

Crop	Insectivorous birds	Target insect and other arthropod pests	Benefits by insectivores bird	Reference
Vegetable crops				
Broccoli	Red-Crested Cardinals	*Trichoplusia ni* and *Artogeia larvae*	More insectivores bird activity	[74]
	Swallows and Sparrows	Aphids, Caterpillars, and Flea Beetles		[85]
	Wild Birds in South Korea	Aphids		[86]
	Savanna Sparrows	Experimental Cabbage Loopers	Pest reduction by 49%	[87]
Beetroot	W. Bluebirds, Chipping Sparrows, Am. Goldfinches, and other insect-eating birds	Beet Armyworms	Reduced Pest by 58%; and consumed around 3% natural Enemies	[54]
Dried Beans	Sparrows, Baya's, Mynahs, and Black Drongos	Bollworm/Pod Borer	Insects damage by 84%, thereby Increasing in yield by 71%;	[88]
Fruit crops				
Apples	CA Scrub and Stellar's Jays, Am. Robins, EU Starlings, Ruby-Crowned Kinglets, N. Flickers, Downy Woodpeckers, Oak Titmice, Brewer's Blackbirds, and Chestnut-Backed Chickadees	Live Experimental Codling Moth Larvae	Reduction of overwintering egg 77–91%;	
	EU Robins, Common Blackbirds, EU Blackcaps, EU Wrens, Great and EU Blue Tits	Aphids, Apple Blossom Weevils, and other arthropods	Reduction in Aphid and natural enemy population	[89]
	Great Tits	Codling Moths	Reduction in pest damage by 11–14% and overwintering pest by 90% thereby increasing yield by 66%	[76]

Table 18.4 (continued)

Crop	Insectivorous birds	Target insect and other arthropod pests	Benefits by insectivores bird	Reference
Cacao	Indonesia Birds Including Flowerpeckers, Sunbirds, and White Eeyes	Arthropods	Yield increased by 31%	[76]
Olives	Birds of Greece	Olive Fruit Flies	Reduced overwintering Pupae by 65–71	[90]
Strawberries	Insect-eating birds (e.g., Black Phoebes, Pacific-Slope Flycatchers), and fruit-eating birds (e.g., House Finches, Am. Robin, EU Starling)	Mainly Lygus Bugs, but also Leaf-rollers and Slugs	Reduced insect damage by 3.8% but created 3.2% birds Damage	[50]
Wine Grapes	Great Tits, House and Tree Sparrows	Greater Wax Moth Caterpillars.	Reduced one-third pest population	[53]
Foodgrain crops				
Corn	Red-Winged Blackbirds	EU Corn Borers	Reduced damage 20% and overwintering Pest by 64–82%	[91]
	Red-Winged Blackbirds	Corn Rootworm Beetles	Reduced insect damage by 50% in early stage of planting but caused 80% crop damage later on	[92]
	Downy Woodpeckers	Corn Borers	Reduction in overwintering insects stages by 34%	[93]
Millet	Senegalese Birds, Including Cattle Egrets, Sparrows, Rollers, Buzzards	Senegalese Grasshoppers	20–26% Pest population has been reduced	[79]
	Grackles, Yellow-Headed Blackbirds, Chipping Sparrows, Bluebirds, Prairie Hens, and EU Starlings	Armyworms	40 avian Species with a significant amount of Armyworms in their gut had been removed	[94]

Table 18.4 (continued)

Crop	Insectivorous birds	Target insect and other arthropod pests	Benefits by insectivores bird	Reference
Wheat	Horned Larks and McCown's Longspur	Pale Western Cut Worms, Grasshoppers, Ants, and Beetles	3 Gut contents revealed 4–70% of Caterpillars	[95]
Commercial crops				
Coffee	Guatemalan Birds Foraging on Insects	Coffee-Berry Borers and other arthropods	Reduced insect pest by 64–80% and foliage damage by 28%;	[96]
Cotton	Ugandan Birds	Experimental Caterpillars	Catches 2–4% insects per day	[97]
	Most important birds: Orioles, Black Bird, Meadlowlarks, Painted Buntings, Quail, Morning Doves, and Mockingbirds	Cotton boll Weevils	28 bird species found with significant amount of boll Weevils in their gut	[97]
Rapeseed and Oilseeds	Ethiopian Birds	Cabbage Flea Beetles, Aphids, Lepidopteran Skeletonizers and Chewing Larvae	Birds decrease leaf damage	[98]
	Common Swifts, Barn Swallows, and House Martins	Cabbage Seedpod Weevils and Pollen Beetle Pests	18–84% of prey consumed crop-damaging pest	[99]
Oil Palm	Oriental Magpie Robin, Ashy Tailor Birds, and Greater Coucal	Several Caterpillars	Reduced damage at an early stage in plants	[98]
Tea	Indian Birds (Asian Pied Starling, Chestnut-Tailed Starling, Jungle Myna, and Red-Vented Bulbul	Geometrid Looper Caterpillars	Reduction in pest populations	[98]
Tobacco	Common Grackles	Tobacco Hornworm	Eaten away 50–100% of insects pest	[98]
	Am. Crows, Mockingbirds, E. Bluebirds, and House Sparrows	Tobacco Hornworm	Reduction in 40–50% of insect populations	[100]

18.5 Improving the population of insectivorous birds

The availability of various resources such as perching trees, nesting trees, and substrates near human inhabitation may encourage insectivorous bird species to inhabit and reproduce. Nest boxes may greatly enhance the insectivorous bird population in the absence of cavities. Using palm and coconut leaf stumps as bird perches in rice fields has boosted insectivorous bird visits. Birds that nest in cavities have specific nest box needs. Similarly, the widespread use of nest boxes may minimize the requirement for chemical spraying and its associated costs in an integrated pest control system. Species-specific box placement should be varied. Various studies created nest boxes for Indian Myna, Brahminy Starling, Bank Myna, Blue Jay, Spotted Owlet, Magpie Robin, and Indian Robin. Bird nest boxes for bug-eating birds may help reduce agricultural pest numbers and avoid pest out breaks. Fixing perches @50/ha in chickpea boosted the effectiveness of predatory birds, including Drongo, Mynas, and sparrow. Some nest specifications for various species are listed in Table 18.5.

Table 18.5: Nest specifications of various bird species (inches).

Species	Diameter of entrance	Entrance height above the bottom	Depth of cavity	Bottom of cavity
Kestrel	3.0	12–14	14–18	8 × 8
Woodpecker	1.25	6–8	8–10	4 × 4
Myna	2.5	14–16	16–18	7 × 7
Blue Jay	2.0	9–12	12–15	6 × 6
House Sparrow	1.0	5–6	6–8	4 × 4
Indian Robin	1.5	7–8	8–10	5 × 5
Swallows	1.5	4–5	6	5 × 5

To improve the insectivorous bird population and replace the chemical usage, peak insect infestation periods may use a combo of bird releases and bio-pesticides. A long-term, comprehensive strategy is needed in this respect, requiring more scientific studies. Chemical recommendations should be based on detailed data on residual levels. Collaborative work of entomologists, ornithologists, and extension agents is needed in technology transmission.

18.6 Birds as a menace to crops and their control

While insectivorous birds have more beneficial and less detrimental consequences, granivorous birds have a more detrimental effect on economic crop and fruit yield. Some farmers employ illegal methods of killing birds using agrochemicals. Other strategies like the wrapping method, reflective bird scaring ribbon, high-density cropping, mechanical bird scare, and herbal repellents (Figure 18.5) are also used not directly to harm bird life. A description of various bird control methods is listed in Table 18.6.

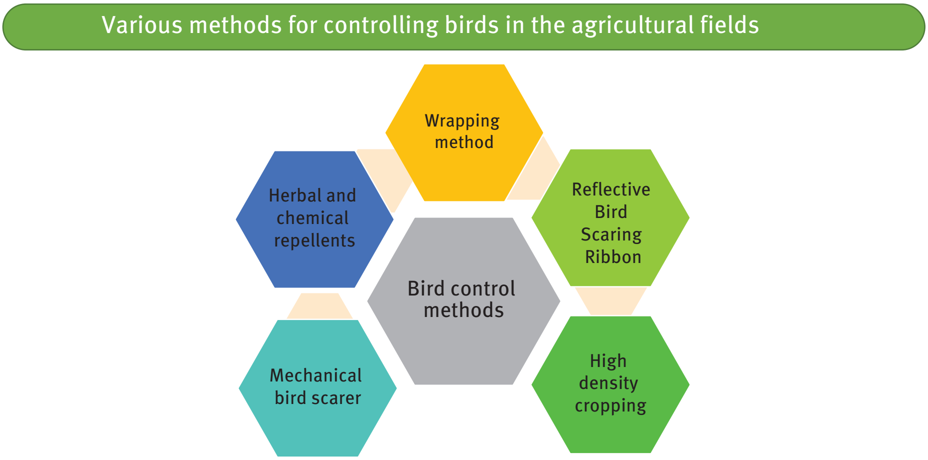


Figure 18.5: Methods for controlling birds in agricultural fields.

18.7 Constraints and uncertainties in the use of birds as insect control

The use of various birds as an agent to control the insects is unreliable, in some cases, as it can cause crop damage, which includes in the ecosystem disservices by birds [101] (Figure 18.6). Ecosystem disservices, or those features of an ecosystem that have a detrimental effect on people, may disproportionately influence conservation choices of farmers. Birds, in particular, might have broader impacts on crops, ranging from beneficial to detrimental. Therefore, it is critical to measure them scientifically. For example, birds may be profuse on farms next to natural areas and help the ecology by eating pests. Birds are opportunistic feeders, and they show facultative responses to a sudden increase in the prey [102]. The major constraint is that the bird species would indirectly consume the beneficial and the potential agents of natural controllers of pest arthropods like a dragonfly, damselfly, and yellow banded wasps

Table 18.6: Various methods for controlling birds in agricultural fields.

Methods	Methodology	Advantages	Crops
Wrapping method	A leaf was wrapped around the cob in two or three loops and secured by a loose knot in the last loop near the top. The objective was to disguise a cob in a leaf.	This procedure is less tedious than scaring and does not need any materials.	Maize
Reflective bird scaring ribbon	The reflective ribbon is a polyester film with a red and silver metallic coating. It is made of a polyester sheet, 1.5 cm wide and 15–20 m long strips. They are attached parallel to the crop at 0.5 m height above the crop using bamboo poles and strings at 5 m intervals. It should be orientated north or south to gain more sunshine.	The use of ribbons to scare birds is extremely successful and acceptable to farmers.	Cumbu and other millets
High-density cropping	Planting the crops with close row and plant spacing	High-density sorghum (fodder crop) and maize planting minimized the grain damage caused by parakeets and other birds. This approach increased the yield, while simultaneously providing fodder.	Sorghum and maize
Mechanical bird scare	It is small machinery, and a basic sound generator works on 1 kilogram of calcium carbide and water for 24 h. This approach efficiently covers 1-hectare areas.	To prevent habituation, vary the firing frequency, location, and direction.	Maize and other grains
Herbal and chemical repellents	Bird damage was reduced in maize and sorghum cropping systems using 200 ml/L Neem cake mixture and 10% Tobacco leaf decoction. A 10% sorghum spray during the lactation stage reduced avian harm. Copper-oxychloride (3 gm/kg seed) reduces bird seedling losses in maize, chickpea, sunflower, and peanut. During the milky stage of sunflower, to repel the insects, the heads are covered with aluminum foil-covered paper plates and sprayed with egg solution @20 ml/lit. Using organic manures like FYM enhances the microclimate and attracts insectivorous birds.	Easy to use	Sorghum, maize, pulses

[103]. When birds prey more on beneficial predatory arthropod insects than on pest species (intraguild predation), they may harm farmers by reducing crop productivity. A soybean field study conducted in Illinois (USA) discovered that plants with birds have far less insect damage to their leaves than in control plots, but their influence on yield was not significant. Thus, the data indicated no net benefit or loss on the productivity of the crop [104].

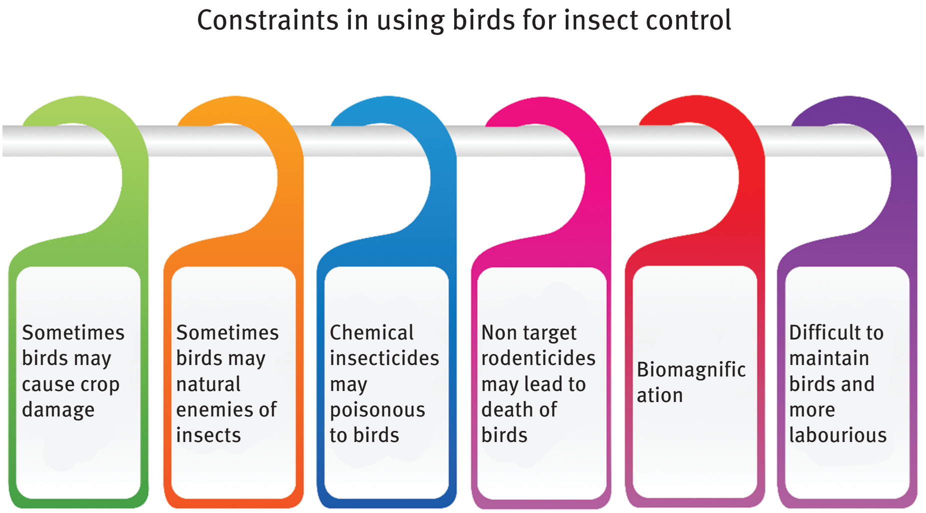


Figure 18.6: Constraints and uncertainties in using birds as biocontrol agents.

Furthermore, studies conducted in Tamil Nadu Agricultural University farms, India, suggested employing the birds, an effective pest biocontrol agent, but not much information is available on their yield losses quantification [9]. Hence, more scientific studies on the ecosystem services and disservices of birds must be done in agricultural ecosystems, with various cropping systems in different agroclimatic regions and seasons.

Syrphid flies and lady beetles are natural enemies of the pest aphid of cereal crops, especially at the high-density times of aphids. These are natural enemies eaten away by insectivorous Eurasian Tree Sparrows (*Passer montamus*) [105]. Birds are considered as vectors of disease-causing enteric pathogens such as *Salmonella enterica*. It was evident that migrating Sandhill cranes were causative agents of the outbreak of Campylobacter in peas [106]. Bird species may adversely affect the cultivars by damaging the crop intraguild predators, leading to economic losses [107].

18.8 Impact of agriculture expansion on bird population

The expansion and intensification of agriculture, such as increased mechanization and high use of chemical pesticides, ultimately affect the birds of croplands. Studies conducted by Tamil Nadu Agricultural University, India, found that many bird visits occurred in organic rice fields rather than conventional chemical-sprayed rice fields [9, 10]. Several studies showed that agriculture-dependent birds are harmed due to the use of pesticides. It is evidenced that insecticides used on rice seeds in nurseries killed Ruddy Shelduck, Lesser-whistling Duck, and Spot-billed ducks. The Indian Peafowl have faced a high degree of threats due to poison baits. The extinction of scavenging birds, such as the vulture and decline of crow and granivorous birds may be attributable to the lingering effects of agrochemicals. The disappearance of several insectivorous birds (Drongos, Bee-eaters) and nesting failure in raptors have been documented at pesticide-contaminated locations in Ambala, Bharatpur, Morena, Thrissur, Parambikulam, Coimbatore, and Andhra Pradesh [108].

Similarly, the pelican population in Karnataka decreased by 2000 [109], and the breeding population of Sarus crane in Bharatpur, Rajasthan, was also found to decline. The presence of different residual levels of organochlorine were detected in several tissues and eggs of bird species, including large Egret, large cormorant, Indian shag, Darter, Grey heron, Cattle egret, and Painted stork [110, 111]. In Corbett National Park, the Himalayan Grey-headed Fishing Eagle has failed to reproduce due to varying levels of pesticide residues [111, 112]. Between 1987 and 1990, Aldrin application on the wheat fields killed 50 collared doves and a few blue rock pigeons in Bharatpur, Madhya Pradesh, and Aldrin residues were found in the gastrointestinal tract of a Sarus crane and a Collared dove. Embryonic maldevelopment, behavioral aberrations in breeding, and physiological disturbances are all impacts. Organophosphate and carbamate compounds could affect singing, attentiveness, and disrupted nesting behavior. So maintaining the balance between deterring predators and encouraging insectivorous birds may be implemented. Several key practices are briefly mentioned below. Some recent studies revealed that these birds were contaminated by chemical residues such as polychlorinated hydrocarbons and dioxins [113–116]. This leads to thinning of eggshells, immature growth of young ones, habitat destruction, food availability, and breeding resources reduction, and finally, mortality [117]. The extensive use of Second Generation Anticoagulant Rodenticide (SGARS) affects nontarget species like Red Kites and barn owls by transfer through the food chain, causing potentially lethal levels of nearly about 30% [118]. According to the studies, extensive large-scale ranching and shifting cultivation of slash and burn agriculture practices adversely affect the birds and allow migration to various habitats other than particular agricultural croplands [119]. This decline in bird population may also occur due to the intentional monoculture of commercial cultivation like biofuel crops [120]. The positive effects of birds as insect control on

farmlands can be improved by promising methods such as bird netting, natural habitats of hedgerows, etc. However, the major implied constraint is that these methods are expensive and make it difficult for widespread application by the farmers.

18.9 Research gaps

18.9.1 Need for advanced studies

Molecular methods should be used in ecological studies of bird and insect relationships. For example, quantifying net impacts and characterizing bird diets using molecular methods may help us understand agroecosystem ecology and its relationship with birds and insects [70, 103]. However, lack of funding and fewer researchers on this science are also major problems in conducting advanced research.

18.9.2 Need for crop-specific and regional studies

Very little research on net impacts has been done on various crop species and locations. It is uncertain that previous generalizable studies on birds across various agroecosystems are usually exaggerate the ecosystem services by birds, but it can be quantified when additional research is undertaken across croplands and geographies [103]. Researchers will not make universal advice but must, instead, adjust their results to each agroecosystem [103, 121].

18.9.3 Need for realistic studies

Studies from the period of economic ornithology typically tell us the role of birds as biocontrol agents, as interpreted by the presence of a pest in a bird's stomach as proof of pest population control [70, 103]. The role of a few bird species in pest control is uncertain to farmers. Conversely, several species implicated as pest control agents may harm crops or devour beneficial arthropods. Many diet studies (molecular or otherwise) will be required to understand better, how different species adjust their diets in various agricultural environments throughout the year.

18.9.4 Need for economic studies

However, a farmer may opt to repel hazardous birds, if the cost of the damage surpasses the expense of the deterrent strategy. In this situation, netting barriers,

falconry, or raptor perches may help reduce bird damage. However, before using bird deterrents, a farmer must determine their cost-effectiveness [103, 122]. Birds may soon be included in regional IPM programs, as more research is being done on their benefits and drawbacks. The emerging science of molecular food analysis will aid researchers in determining which birds contribute to net impacts and in what agricultural scenarios.

18.9.5 Need for collaborative work

Researchers must work closely with stakeholders to acquire relevant data for critical decision-making phases (e.g., adoption, planning, intervention, assessment) [103, 121]. The decline of economic ornithology is due to a lack of practical advice and stakeholder participation [69, 70]. To maintain stakeholder support, admit when to use and when birds cannot be used as biological control agents. For example, blueberries and cherries are high-energy foods for various fruit-eating birds [103, 123]. In some cases, rather than improving services, it may be required to investigate techniques to reduce disservices (e.g., bird netting or falconry). Generalizing some bird species as beneficial or pests may not be fair, without any scientific assessment. Collaborating with farmers, landowners, and other stakeholders to convey this context-specific knowledge is critical. Scientists must work closely with farmers, landowners, and other stakeholders to guarantee the delivery of ecosystem services by birds (e.g., insect control) [103, 124].

18.9.6 Planning and policy to incorporate in IPM

Though many studies on birds have already been done, it is unclear how avians as biological control agents fit into IPM plans. Using natural enemy measures to integrate arthropod natural enemies into IPM decision-making in wheat, soybean, and walnut cropping systems may give promising results [103, 125, 126]. From economic ornithology to bird net effects and ecosystem services, the study of birds in agroecosystems has to be evolved. In addition, this research might provide valuable information on how certain bird populations affect specific crops in specific places [103].

18.10 Future scope and perspectives

Studying the agroecosystem of birds through ecosystem services and disservices allows us to revisit the insights given in economic ornithology developed in earlier days. However, the current studies on birds in insect control need several changes.

First, there is a strong need to conduct advanced studies in molecular biology, regionally specific, crop-specific, and agroecosystem-specific studies. The studies should also report the realistic scenario of using birds as biocontrol of insects without bias and exaggeration. Finally, economic analysis should be done to know the feasibility of the birds as biocontrol agents, especially in changing climatic conditions. After the economic analysis, the planning and policy to incorporate in IPM should be done, if it is economically feasible (Figure 18.7).

Figure 18.7: Future scope, perspectives, and research gaps in biocontrol of insects by birds.

18.11 Conclusion

Birds provide various ecosystem services; among them, one of the most important services is insect and pest regulation. As a consequence of their usefulness to farmers, it is advocated that most birds in the agro-environment should be protected, since they are beneficial in one way or another. It is vital to organize periodic awareness programs on the importance of birds to benefit farmers in maximizing their profits. It should also be made clear to people that they should not cause harm to perch and nesting areas. An artificial perch will be placed amid crops to attract more birds to the region, and this will be done in future. Maintaining biofencing in the agricultural farm lands may shelter many bird species that serve as insect predators. In order to minimize reliance on chemical fertilizers and pesticides, it is necessary to encourage the use of biological fertilizers and biological control agents, as this approach will not cause harm to birds. More research on nesting performance of commercially important bird species, breeding time, and the coincidence of these with the crop stages is the need of the hour, as this vital

ecosystem service is highly underexplored scientifically. It is the right time for fruitful research to be carried out on this aspect in order to include insectivorous birds as a vital component in the Integrated Pest Management system.

Work contribution

G. K. Dinesh, Writing – first draft, data visualization, Software; **B. Priyanka,** Writing – first draft; **Archana Anokhe,** Writing – first draft; **P. T. Ramesh,** Writing – review and editing; **R. Venkitachalam,** Writing – review and editing; **K. S. Keerthana Sri,** Writing – review and editing; **S. Abinaya,** Writing – review and editing; **V. Anithaa,** Writing – review and editing; **R. Soni,** Writing – review and editing.

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